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TECHNICAL REPORT

NO. 12958

RADIAL LOAD TEST OF AN ALUMINUM ROADWHEEL

FOR THE M1 ABRAMS MAIN BATTLE TANK

(INTERIM TECHNICAL REPORT)

MARCH 1984



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by

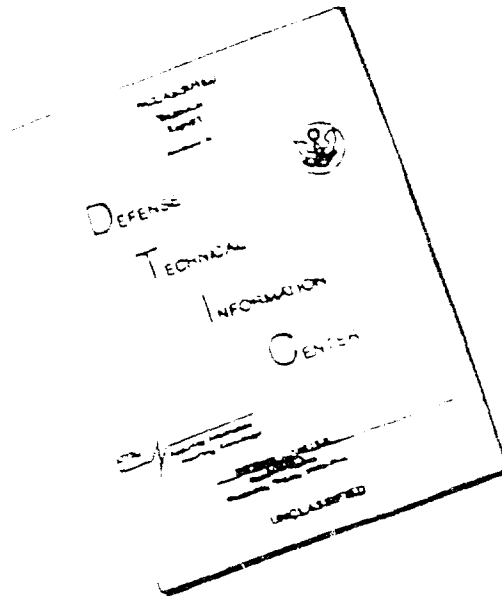
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A Composite roadwheel for the US Army M1 Abrams Main Battle Tank has been designed for volume production. The composite roadwheel uses an E-glass/epoxy advanced composite material, produced by wet filament-winding followed by compression molding at a high temperature to compact and cure the matrix. Aluminum inserts are used to resist corrosion and creep at the bolted interfaces between the component and the vehicle. Stress analysis using NASTRAN finite-element computer models, (Cont'd)		

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combined with validation tests on an aluminum roadwheel, have been used to establish the strength of the existing aluminum wheel, and to evolve a composite wheel of comparable strength.

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1.0. INTRODUCTION

This project was conducted as part of the Manufacturing Methods and Technology program. Contract No. DAAE07-83-C-R082 was awarded to Composittek Engineering Corporation (a subsidiary of the Kelsey-Hayes Company) in August 1983, by the US Army Tank Automotive Command. The contract involves establishing a process to automate the fabrication of fiber-reinforced plastic (FRP) composite roadwheels for the M1 Abrams Main Battle Tank.

A Key element in demonstrating the viability of the composite wheel manufacturing process is to establish a method of qualification testing for the composite roadwheel. The reason for this testing is to establish that the composite wheel is equivalent, in both strength and durability, to the existing aluminum roadwheel design. In order to develop a test procedure for the composite wheel, it was necessary to test an aluminum roadwheel to measure its strength. An aluminum roadwheel, part no. 1227-4482, was supplied to Composittek by General Dynamics Land Systems Division at no cost to the contract.

This report details the results obtained from tests carried out by Composittek Engineering Corporation on the aluminum roadwheel.

2.0. OBJECTIVE

The objective of this test was to simulate the worst loading conditions experienced by the roadwheel when mounted on an M1 tank, and to find both the ultimate and fatigue strength of the wheel. These results would be used to validate a NASTRAN finite-element model of the wheel.

3.0. CONCLUSIONS

The NASTRAN finite-element model correlated well with the limited strain gage data obtained during the test. However, due to differences between the NASTRAN model and the behavior of the actual wheel (and associated mounting), the measured stresses were lower than the predicted stresses by a factor of 0.53.

4.0. RECOMMENDATIONS

A suggested duty-cycle for the aluminum roadwheel, based on best-available data, has been supplied to Composittek by TACOM. (See Addendum.) This cycle suggests a peak cycle load of 79,000 lbs (351.4 kN) and a total of about 1.2×10^6 load cycles. If the stresses in the aluminum wheel follow the pattern of the finite-element model stresses, then the peak stress seen in the wheel under a 79,000 lbs. radial load will be around 70 ksi (482.6 MPa). Data given in MIL HDBK 5A-1966

suggests that the 2014-T6 aluminum alloy used in the wheel has a yield strength of 60 ksi (413.7 MPa) and a fatigue strength of 29.5 ksi (203.4 MPa) at 1.2×10^6 cycles. On this basis, the allowable ultimate load for the wheel would be 68,000 lbs. (302.5 KN), and the allowable fatigue load, 33,000 lbs. (146.8 KN). These figures should be used in the design and testing of the composite roadwheel.

5.0. DISCUSSION

5.1. Test Fixture

A finite-element structural model of the aluminum roadwheel, constructed using the MSC-NASTRAN program, had been finished by Composittek before physical testing of the aluminum wheel. The constraint, loading and instrumentation applied to the test wheel, were configured to conform as closely as possible both to the actual vehicle installation and to the finite-element model. Comparison of measured test results with NASTRAN-predicted results, allows the actual stress profile throughout the wheel to be predicted with greater confidence than could be obtained from the finite-element model in isolation.

When installed on the M1 tank, roadwheels are mounted in pairs and bolted, "back-to-back", to a steel hub using a ring of 10 bolts. To simulate this, the test wheel was bolted between a pair of 1" (25.4 mm) thick steel plates, relieved as necessary to accommodate strain gages. The wheel and plates were supported on a steel axle between two columns, as shown in Figure 5-1, to allow vertical radial loading through the rubber tire at the top of the wheel. A steel wear-ring, as fitted to roadwheels in the vehicle installation, was bolted to the outside face of the wheel.

The completed test fixture was installed in a Tinius-Olsen compressive-load test machine, having a maximum load capacity of 60,000 lbs. (266.9 KN). For the purpose of this test, manual load selection and monitoring was used.

5.2. Instrumentation

The aluminum roadwheel was fitted with 2-axis Micro-Measurements 350 ohm strain gages bonded directly to the wheel surface in the position shown in Figure 5-2. The gages were oriented so that one gage of each pair read radial strain, and one gage read hoop strain. The output from the gages was sampled and recorded digitally on demand using a 7-channel BLH Electronic data-logger.

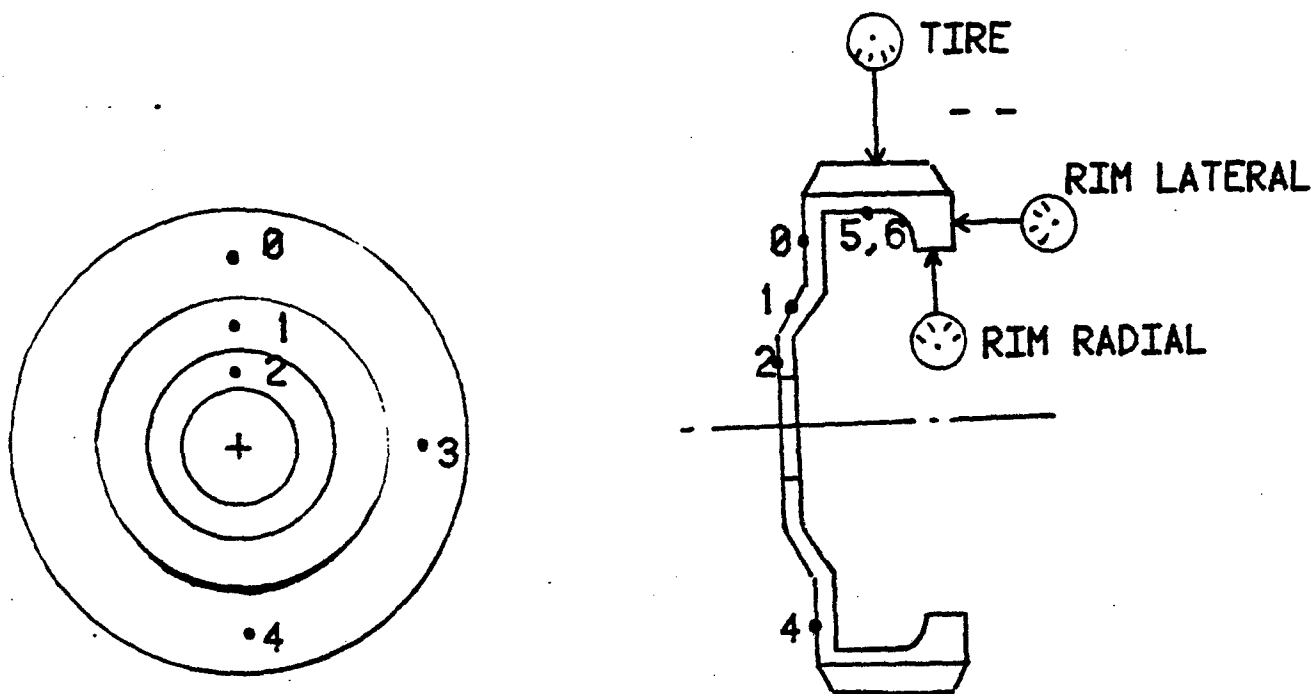


FIGURE 5-2: STRAIN GAUGE & DEFLECTION POSITIONS

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TABLE 5-1: PEAK STRAINS & STRESSES RECORDED

GAGE	DIRECTION	MAX LOAD		MAX STRAIN (MICRO IN/IN)	STRESS		STRESS @ 158,000 LB.	
		(LB)	(KN)		(PSI)	(MP2)	(PSI)	(MP2)
0	Radial	60,000	266.9	341	3580	24.68	5000	34.47
1	Radial	60,000		-1602	-16820	-116.0	-43750	-301.6
2	Radial	60,000		-14	-150	-1.034	-1250	-8.62
3	Radial	60,000		-968	-10160	-70.05	-19400	-133.8
4	Radial	60,000		+1747	18340	126.4	40600	279.9
5	Radial	60,000		+2772	29110	200.7	76700	528.8
6	Hoop	60,000		-110	-1160	-8.	-3400	23.4

TABLE 5-2: PEAK DEFLECTIONS RECORDED

LOCATION	DIRECTION	MAX LOAD		MAX DEFLECTION		DEFLECTION @ 158,000 LB.	
		(LB)	(KN)	(IN)	(MM)	(IN)	(MM)
Rim	Radial	60,000	266.9	0.21	5.334	0.55	13.97
Rim	Lateral	60,000		0.34	8.636	1.01	25.654
Tire	Radial	60,000		0.86	21.844	1.61	40.894

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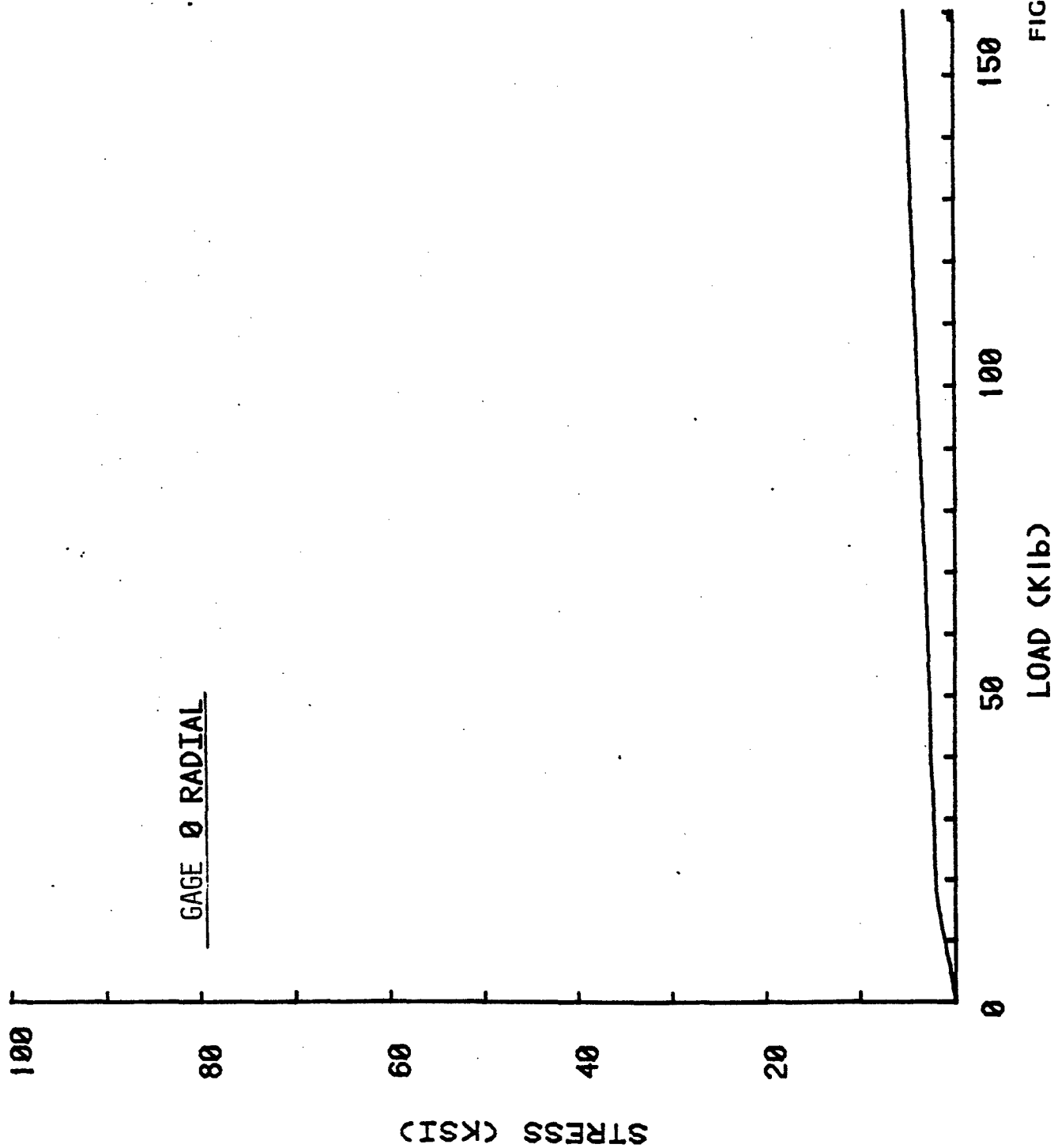


FIGURE 5-3

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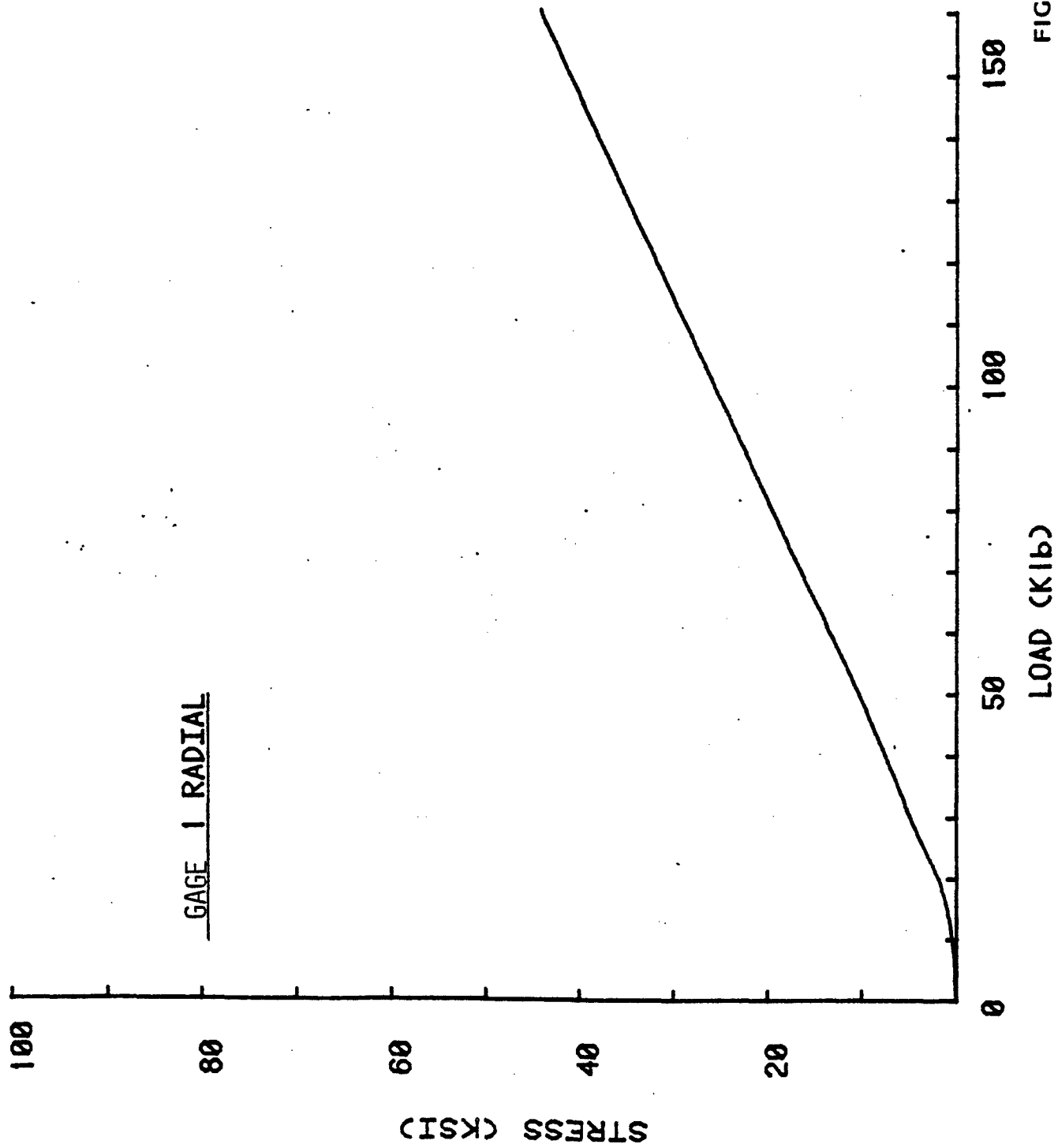


FIGURE 5-4

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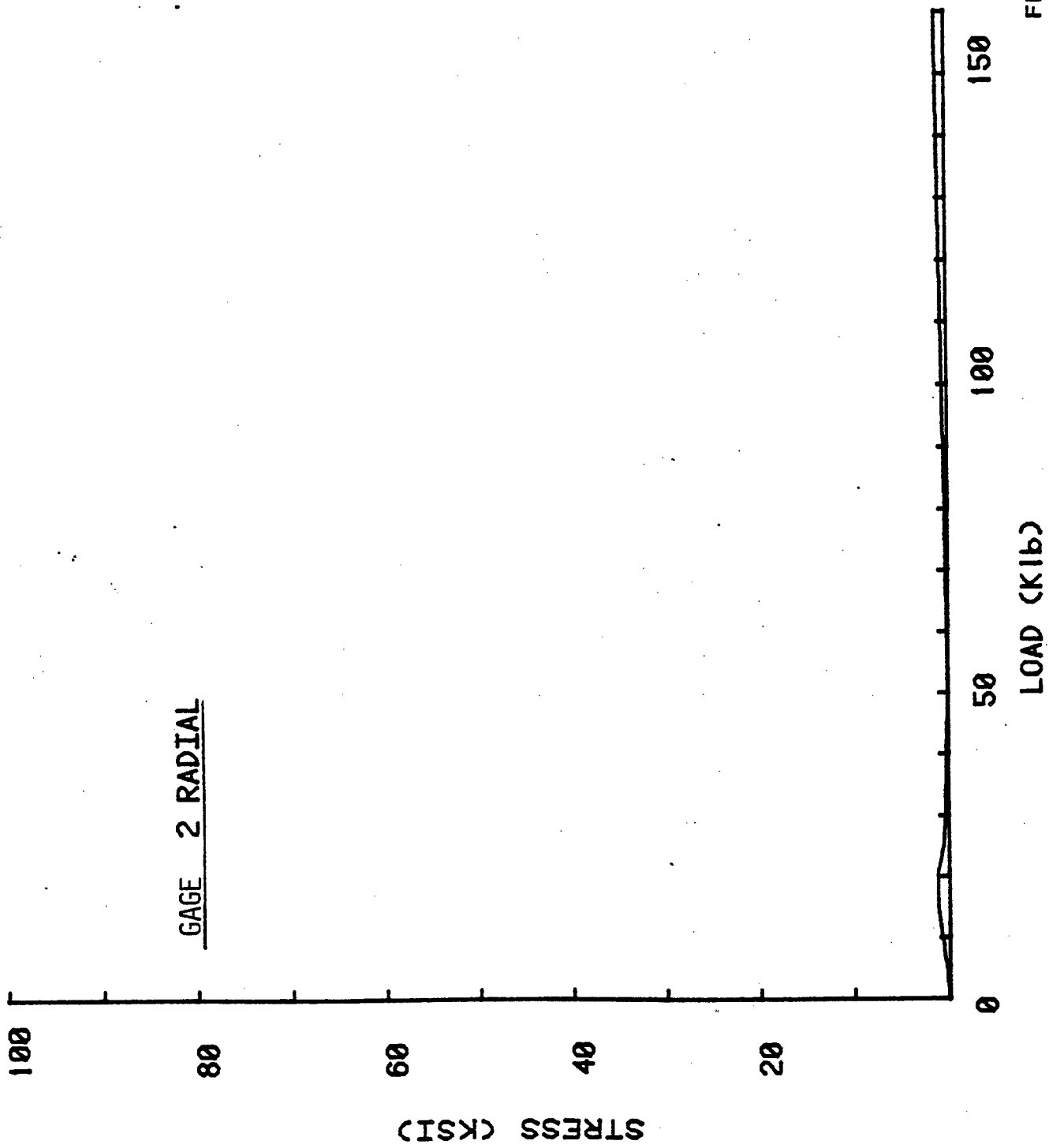


FIGURE 5-5

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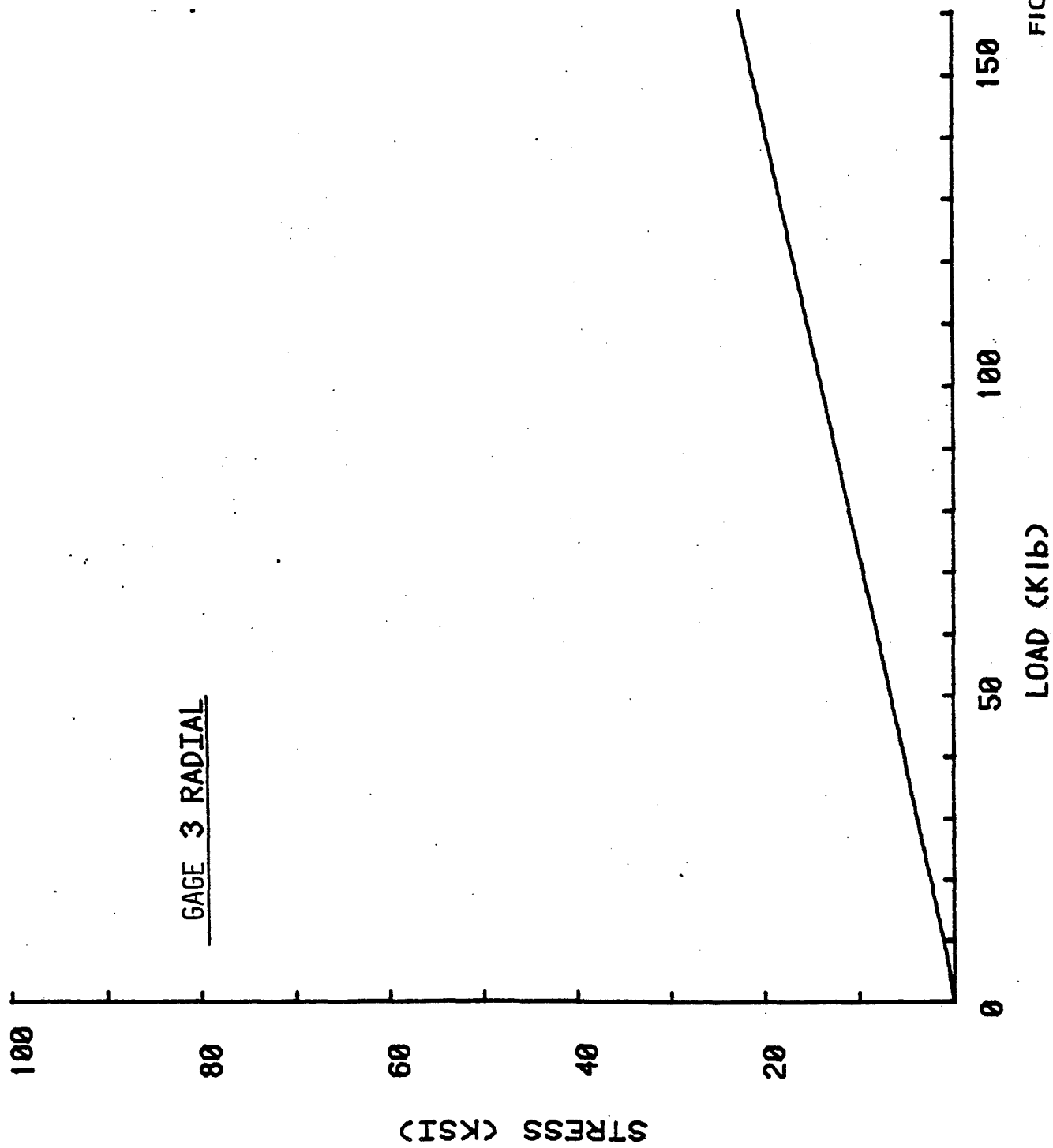


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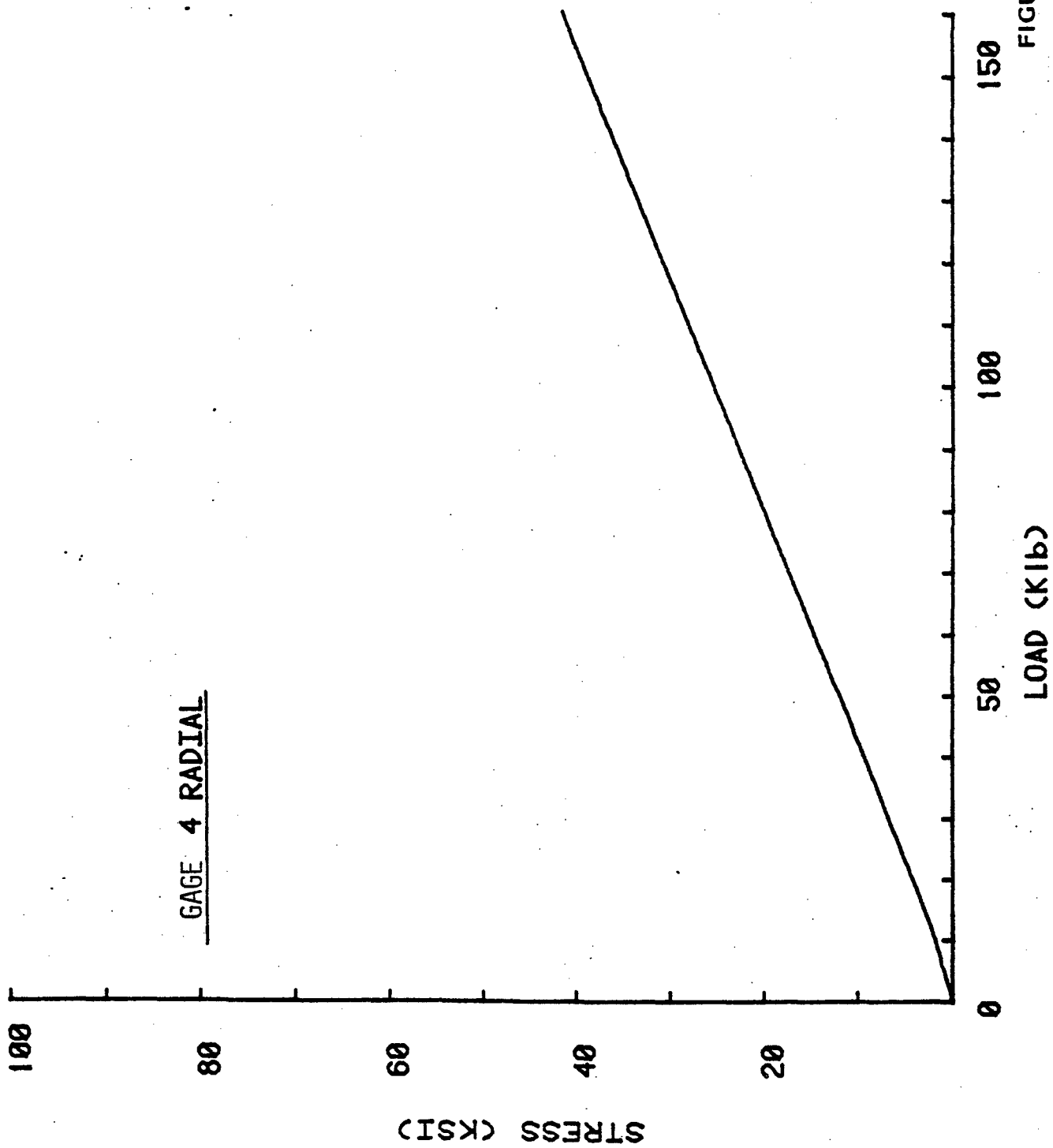


FIGURE 5-7

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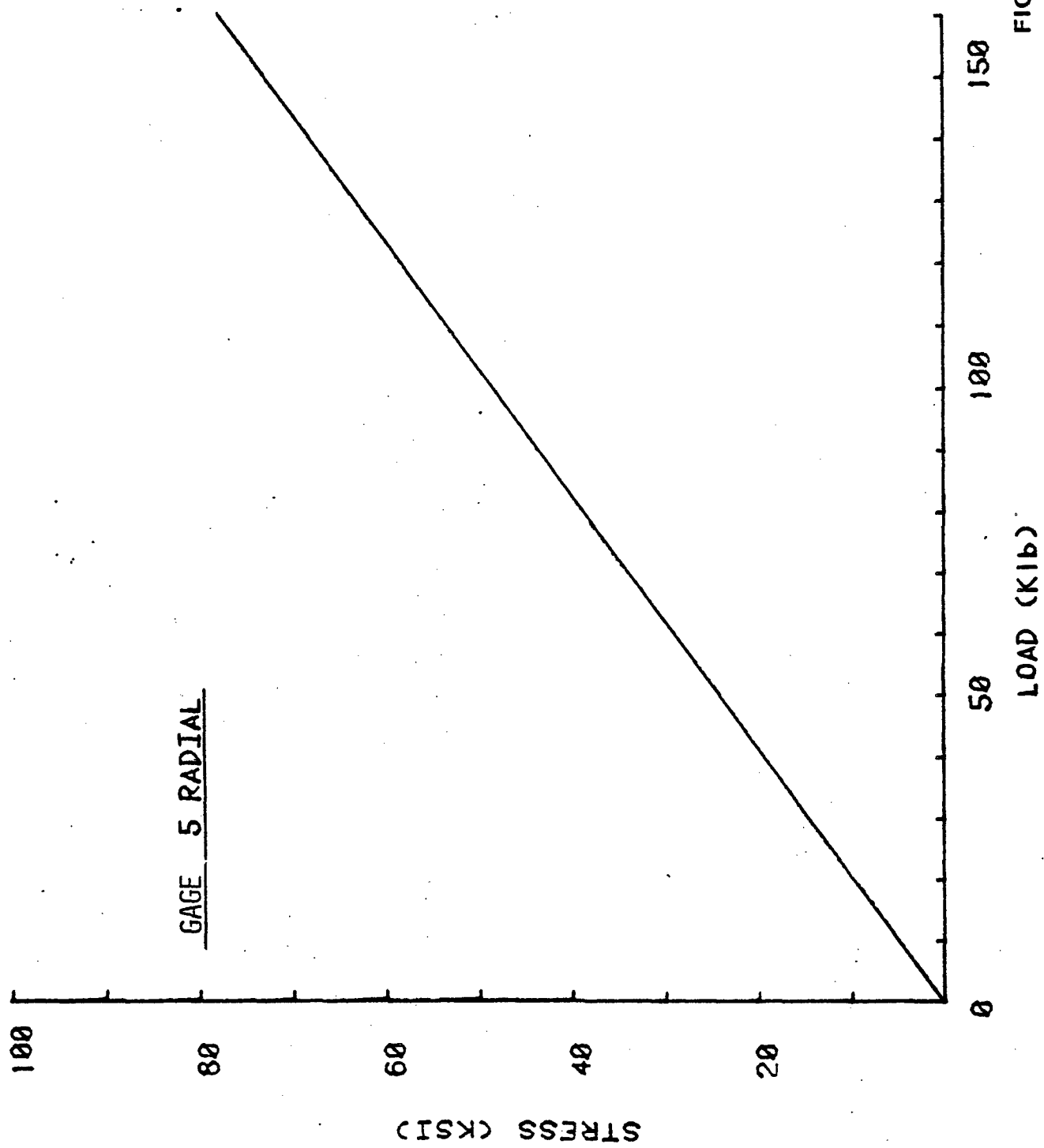


FIGURE 5-8

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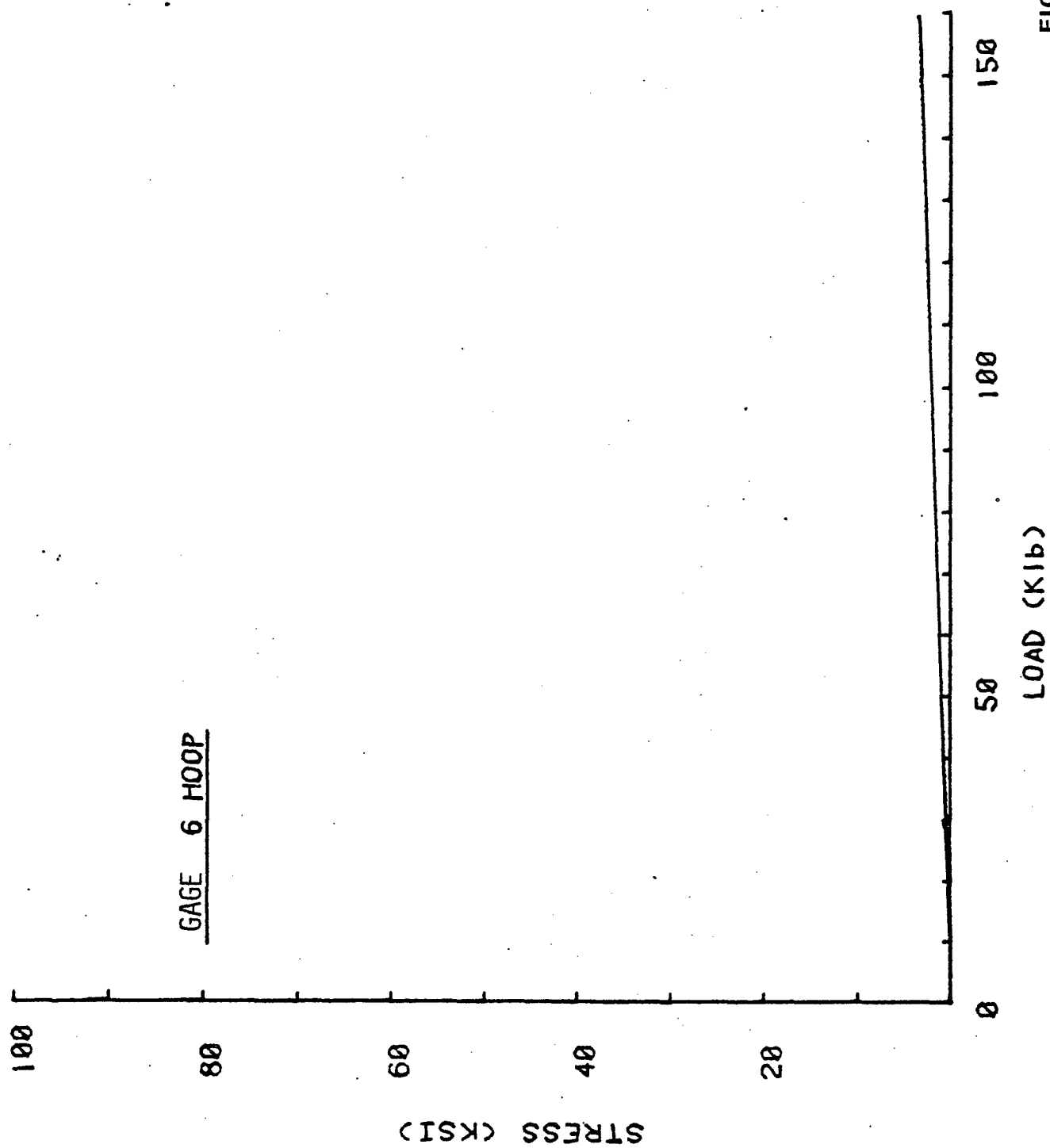


FIGURE 5-9

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Under the peak load of 60,000 lbs. (266.9 kN), the tire experienced a net deflection of 0.86 in. (21,844 mm). Radial and lateral deflections at rim under this load were 0.21 in. (5.334 mm) and 0.34 in. (8.636 mm) respectively. These are equivalent to deflections of 1.61 in. (40.894 mm), 0.55 in. (13.97 mm) and 1.01 in. (25.654 mm) respectively under a radial load of 79,000 lbs. (351.4 kN). Maximum deflections are tabulated in Table 5-2, and load-deflections characteristics at each position measured are plotted in Figures 5-10 to 5-13.

Radial hoop stresses from gages 0, 1, 2, 5, and 6 are presented for direct comparison with NASTRAN-predicted stresses in Figures 5-14 to 5-16.

5.5. Discussion of Results

After initial "settling" at applied loads up to 15,000 lbs. (66.7 kN), the load/strain characteristics for all gages are linear within the test range of 0-60,000 lbs. The initial settling may be attributed to load-sharing effects as the loading platen beds down into the tire. To give a comparison with the finite-element model output, strain gage outputs were extrapolated linearly.

Comparison of the measured, extrapolated strains with the finite-element output (Figure 5-15) shows a reasonable correlation, given the relatively small number of data points measured. In general, the measured strains/stresses in the radial direction are reduced by a factor of 0.53 from the predicted stresses. This reflects the beneficial effects of 3-dimensional load sharing in highly-stressed areas. This effect is not accurately simulated in the finite-element model, leading to exaggerated stress peaks. The only significant deviation of the measured stresses from the predicted pattern is in the hub area, around the mounting holes, where the stressed measured were much lower than predicted. This reflects the unduly-harsh effect of assuming the wheel to be restrained only at the bolt-holes in the finite-element model compared with the load-spreading contributed by the mounting flanges used in the vehicle installation.

Predicted hoop stresses were generally relatively low. The single data point measured in the hoop direction correlates well with the predicted value (See Figure 5-16).

The measured deflections of the wheel reflect the strain gage results. The lateral deflection at the rim (Figure 5-12) is greater than the radial deflection (Figure 5-11), suggesting that the likely eventual mode of failure will be buckling of the wheel disk. This correlates with the high stresses predicted in this area.

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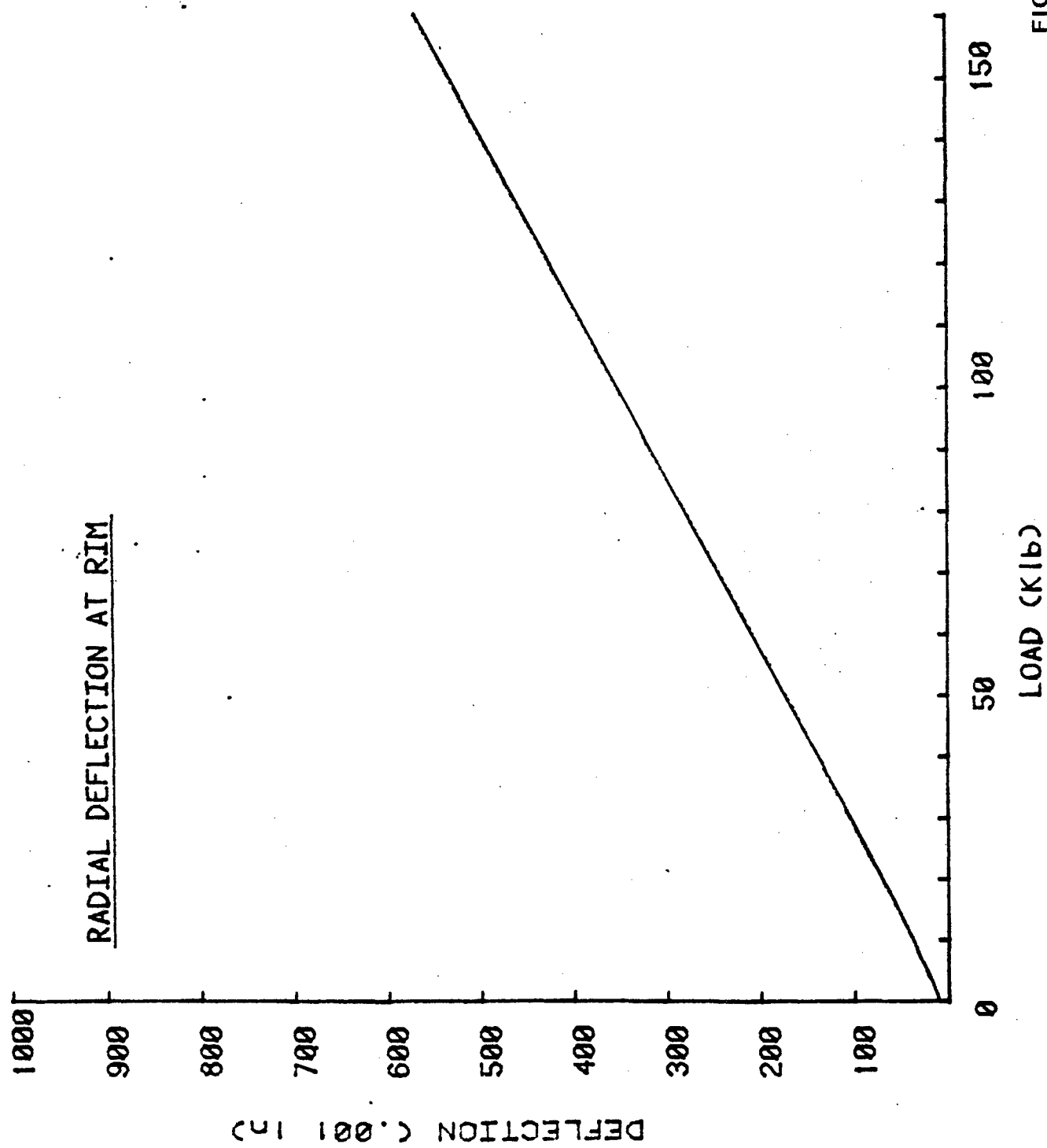


FIGURE 5-10

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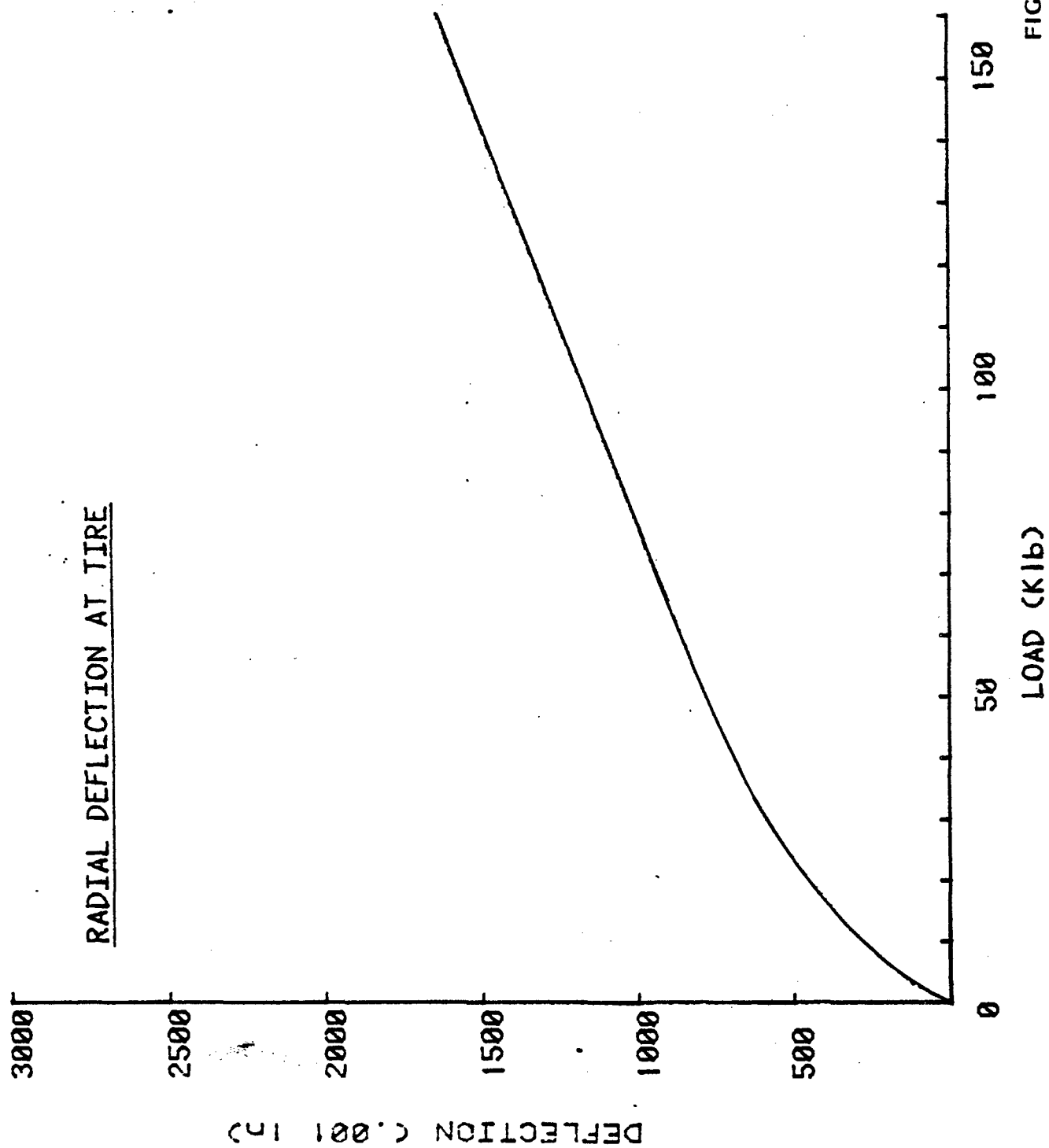


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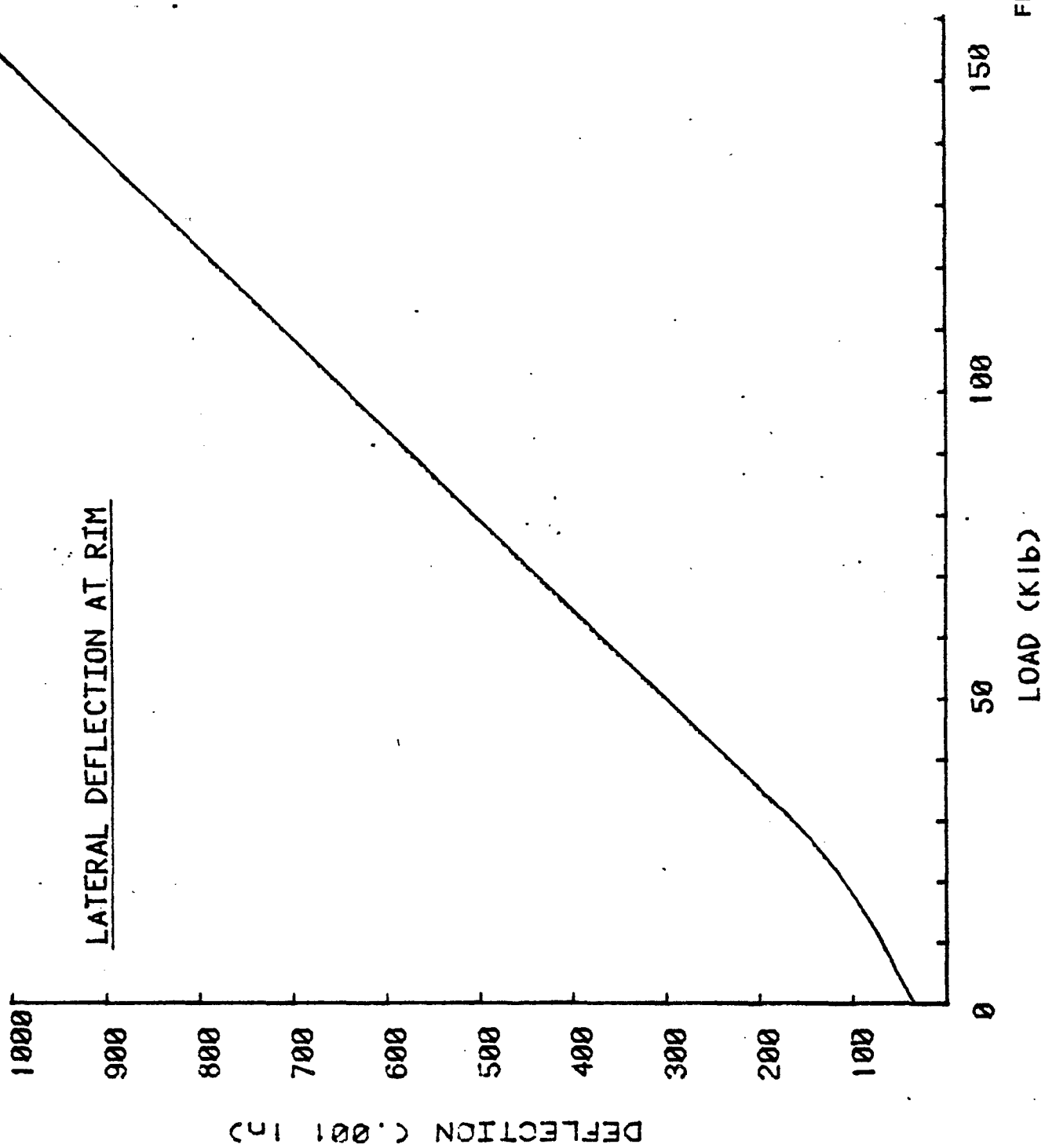


FIGURE 5-12

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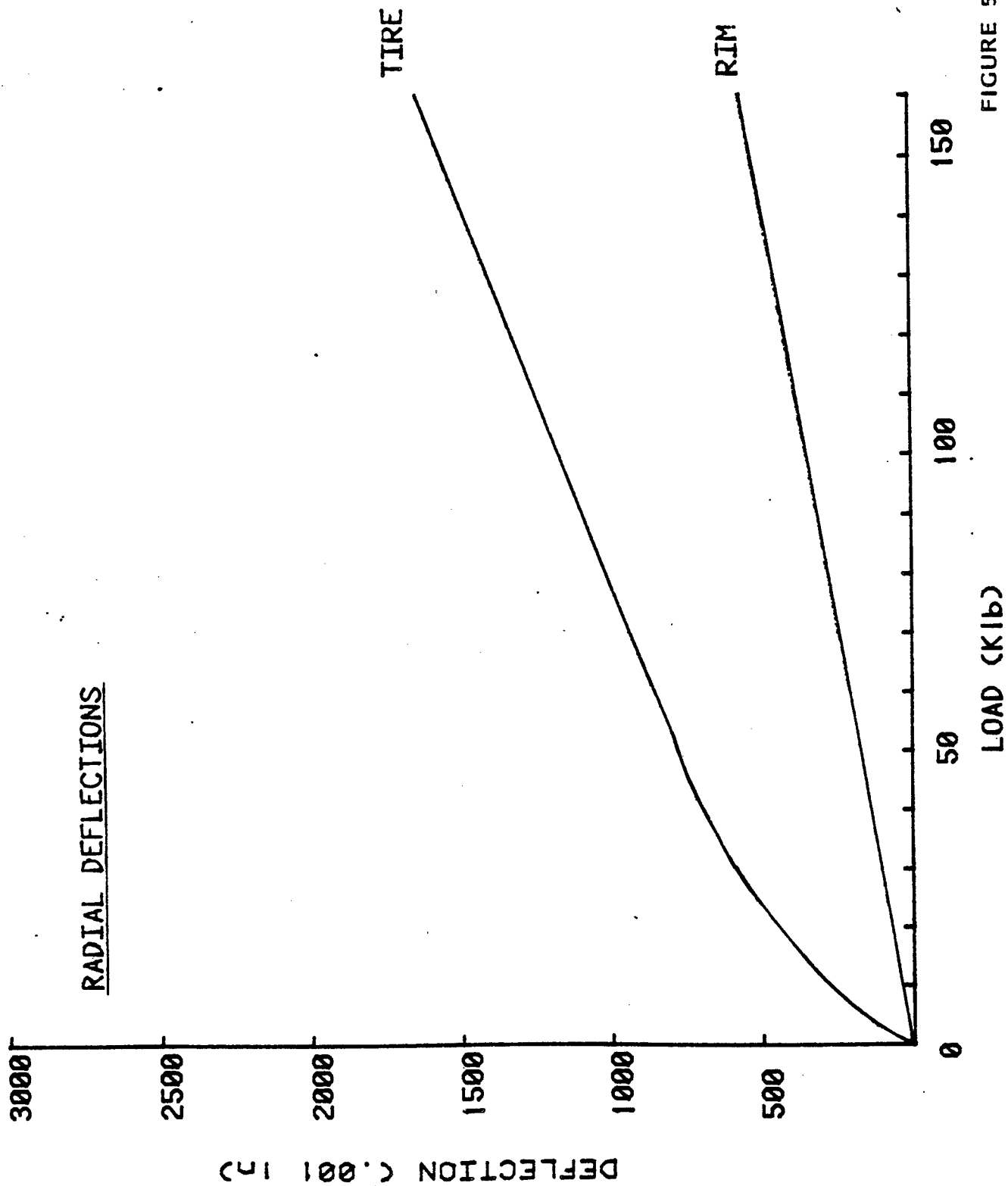


FIGURE 5-13

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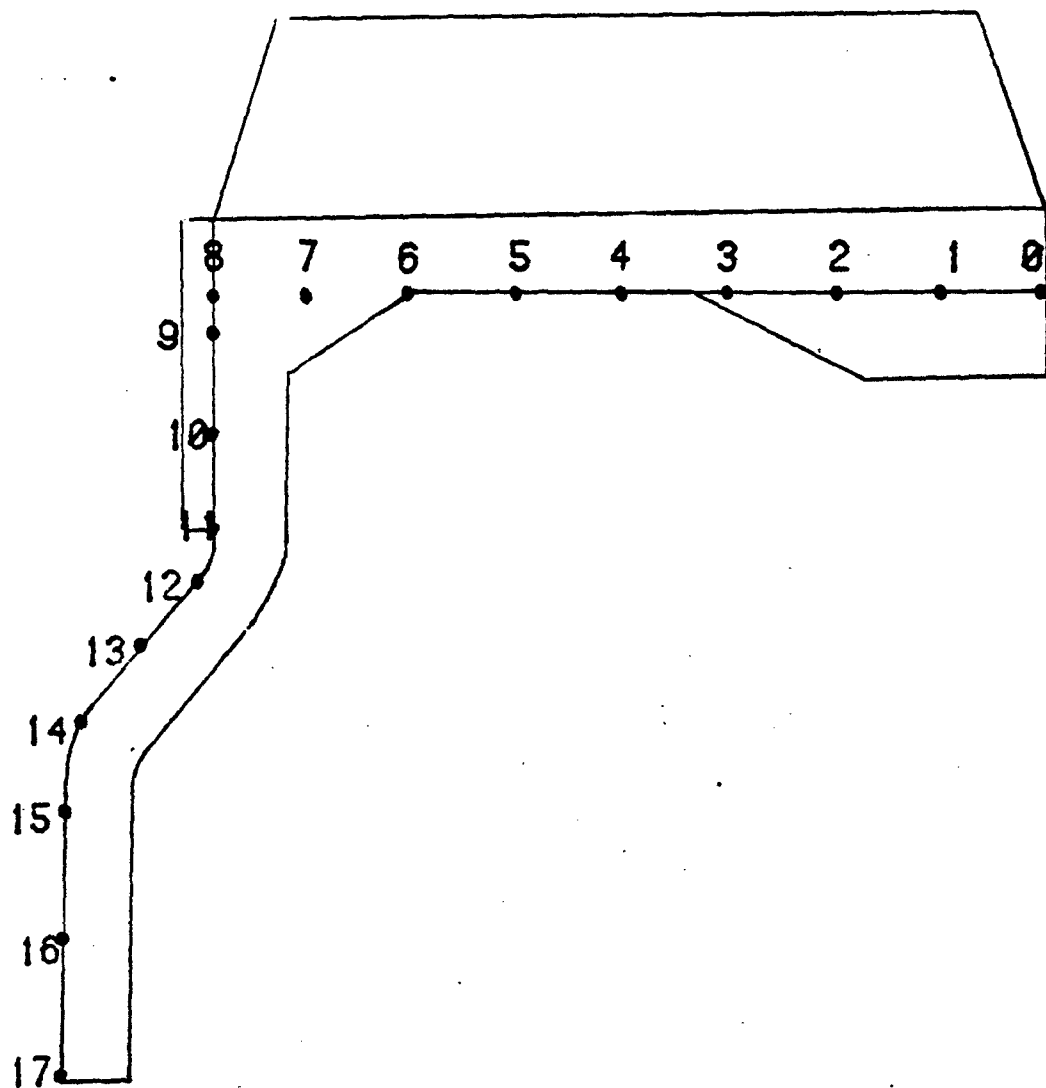


FIGURE 5-14: IDENTIFICATION OF STRESS LOCATIONS

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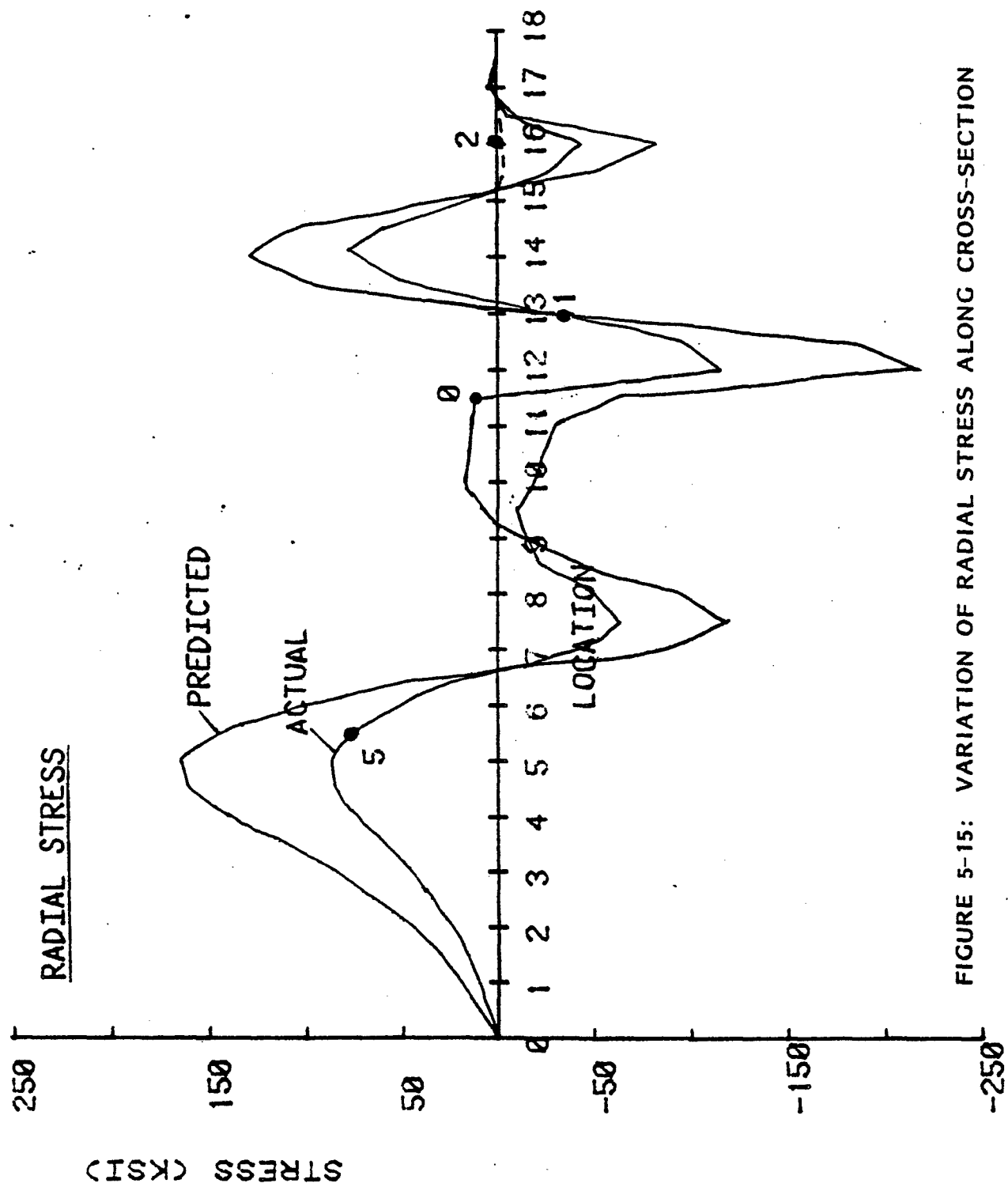


FIGURE 5-15: VARIATION OF RADIAL STRESS ALONG CROSS-SECTION

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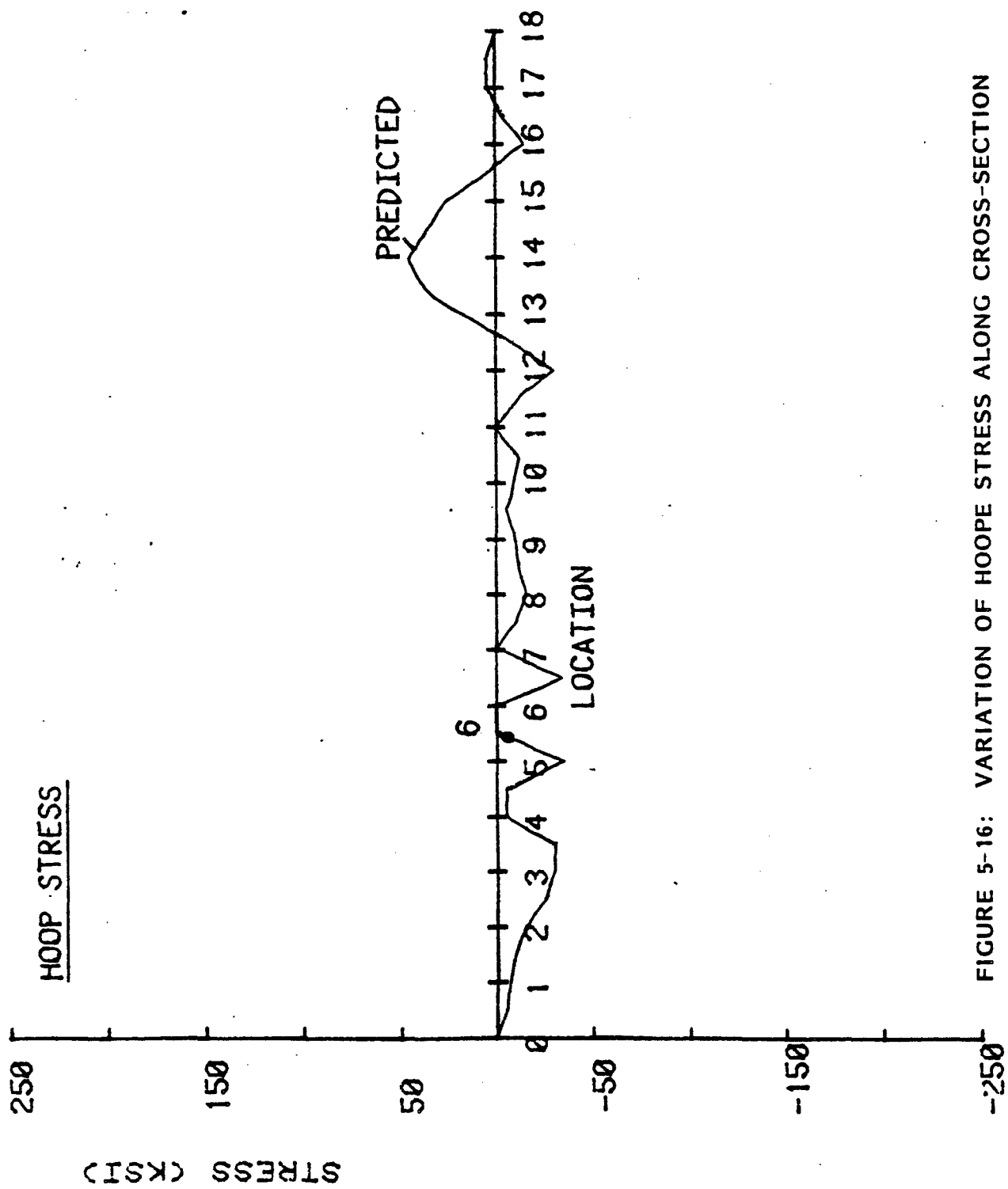


FIGURE 5-16: VARIATION OF HOOPE STRESS ALONG CROSS-SECTION

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ADDENDUM

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DUTY CYCLE

Radial Load, LBS	Radial Loading Ratio		# Cycles	Lateral Load, LBS
	minimum	maximum		
18000	0		40,600	4500
18000	0.2		209,000	4500
18000	0.4		250,000	4500
18000	0.7		132,000	4500
20000	0.4		31,500	5000
22000	0.7		20,000	5500
24000	0.2		211,000	6000
26000	0		76,000	6500
35000	0		44,500	9000
36000	0.2		62,000	9000
45000	0		43,000	0
55000	0		44,500	0
62000	0		12,700	0
80000	0		15,000	0
158000	0		13,000	0

The duty cycle is a conservative estimate of the dynamic loads which the track exerts on one roadwheel station. There are two roadwheels per roadwheel station. The lateral load of the duty cycle is a constant load due to cornering of the vehicle. The radial load is cycled. As an example, a radial load of 18,000 pounds, radial loading ration of 0.2 for 209,000 cycles and a lateral load of 4,500 pounds means that the load imposed on the roadwheel by the track cycles from a maximum of 18,000 pounds to a minimum of 3,600 pounds for 209,000 cycles with a constant lateral load of 4,500 pounds. When determining test procedures, the vehicle's governed maximum speed of 45 miles per hour should be considered.

ADDENDUM: DUTY CYCLE FROM CONTRACT NO. DAAE07-83-R082

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